FERMILAB

Extruded scintillator for calorimeter applications

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For Northern Illinois Center for Accelerator and Detector Development

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Why do we need to consider the use of extruded scintillator in calorimetry.

- **It is simple production process.**
- **It is stable during long production run.**
- **It is robust while using WLS fiber as a read out.**
- **It is cheap ! (~$10 /kg when you order >10 T).**
- **LY of extruded scintillator is as high as KURARAY SCSN-81***
- **Mechanical tolerance is comparable to the cast scintillator .**
- **Multiple applications are pending.**
- **Coupling with Solid State Photomultiplier (SSPM: MRS, SiPM, GM-APD) comes in the natural way.**

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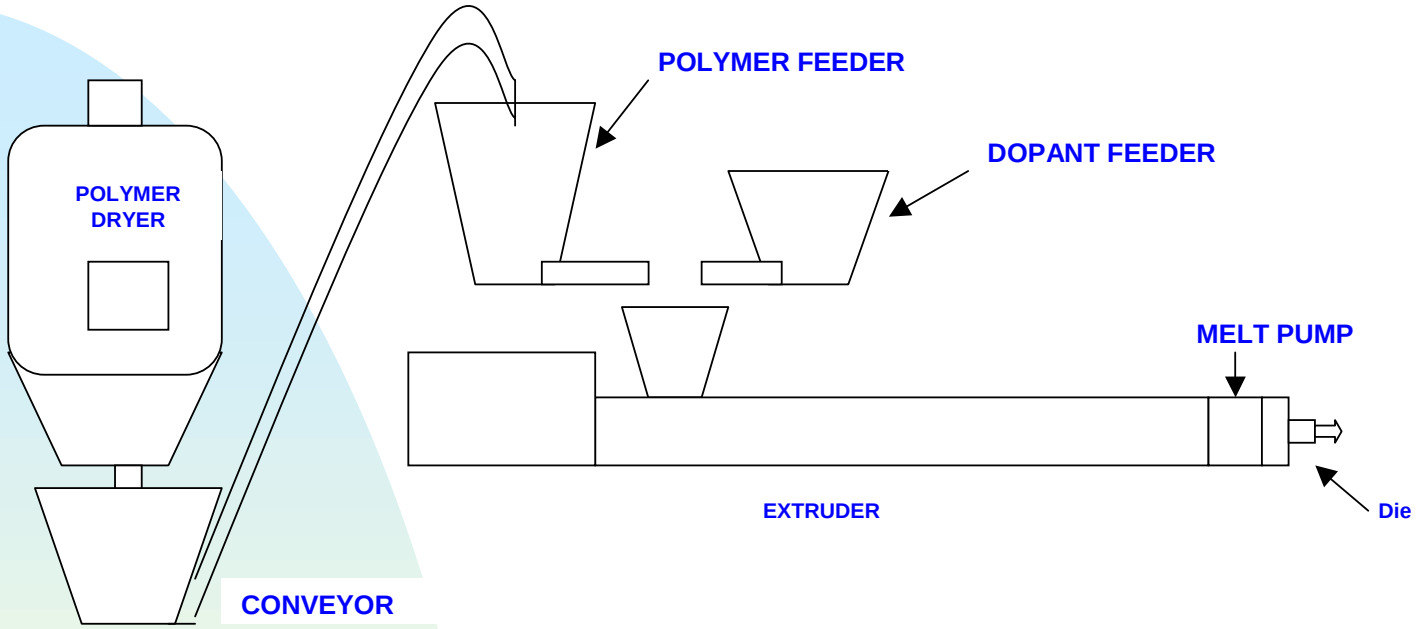
FNAL-NICADD EXTRUSION FACILITY



- Line under nitrogen atmosphere:
  - Drying under nitrogen
  - Each piece of equipment is purged
- In-line continuous process:
  - Less handling of raw materials
  - Precise metering of feeders
  - Twin-screw extruder (better mixing)
  - Melt pump offers steady output
  - Control instrumentation

ZE 40A UTS Technical Data

Output range 30-200kg/h

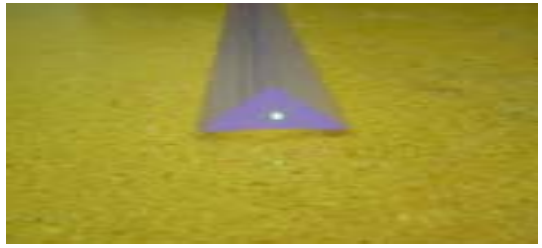
Screw diameter	44 mm
Screw speed	1200 RPM
Drive power	200 HP
Height	~1100 mm
Weight	~3500 kg
Lifetime	~40000 hours

Extruder and co-extruder

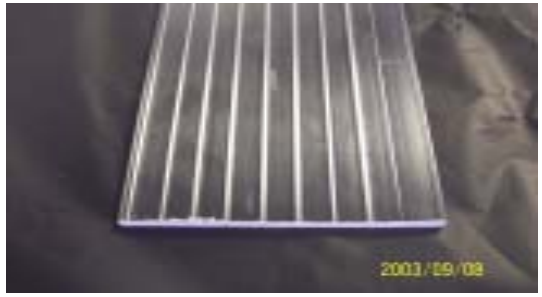
Die impact on the scintillator profile

Rectangle, with or without hole to host 1.2 mm WLS fiber

Triangle, with or without hole to host 1.2 or 1.5 mm WLS fiber



Rectangle, with 10 holes, or without them, to host 1.2 mm WLS fibers



Triangle with co-extruded TiO2 coating .

Parameters of extruded and co-extruded scintillator

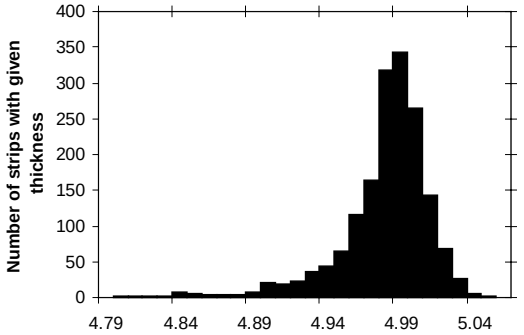
Thickness: σ ~ 0.6 % (Over 300 m)

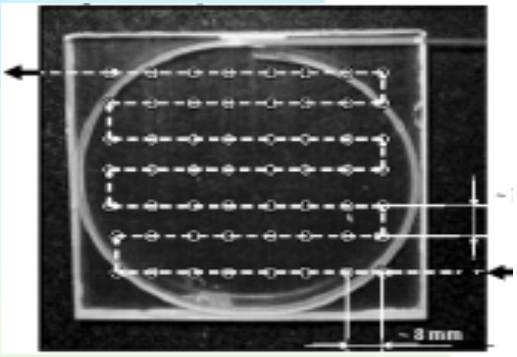
Width : σ ~ 0.2 % (Over 300 m)

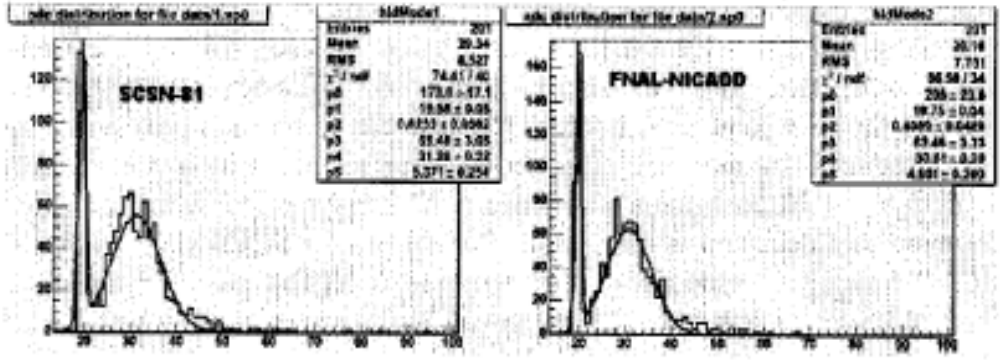
LY non-uniformity σ ~ 2.2 % (10*10 cm^2)

Light Yield 66 % of BC408

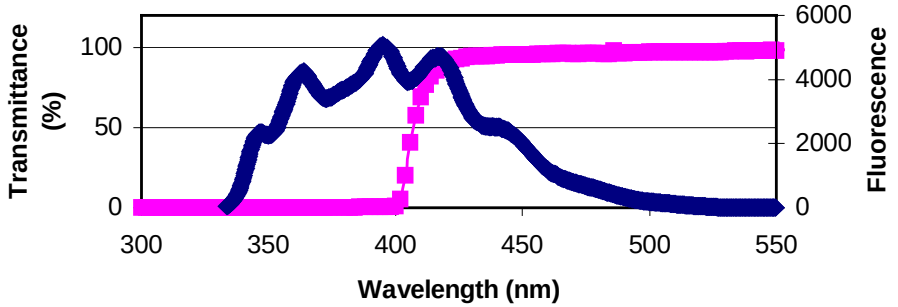
~100% of Kuraray SCSN-81



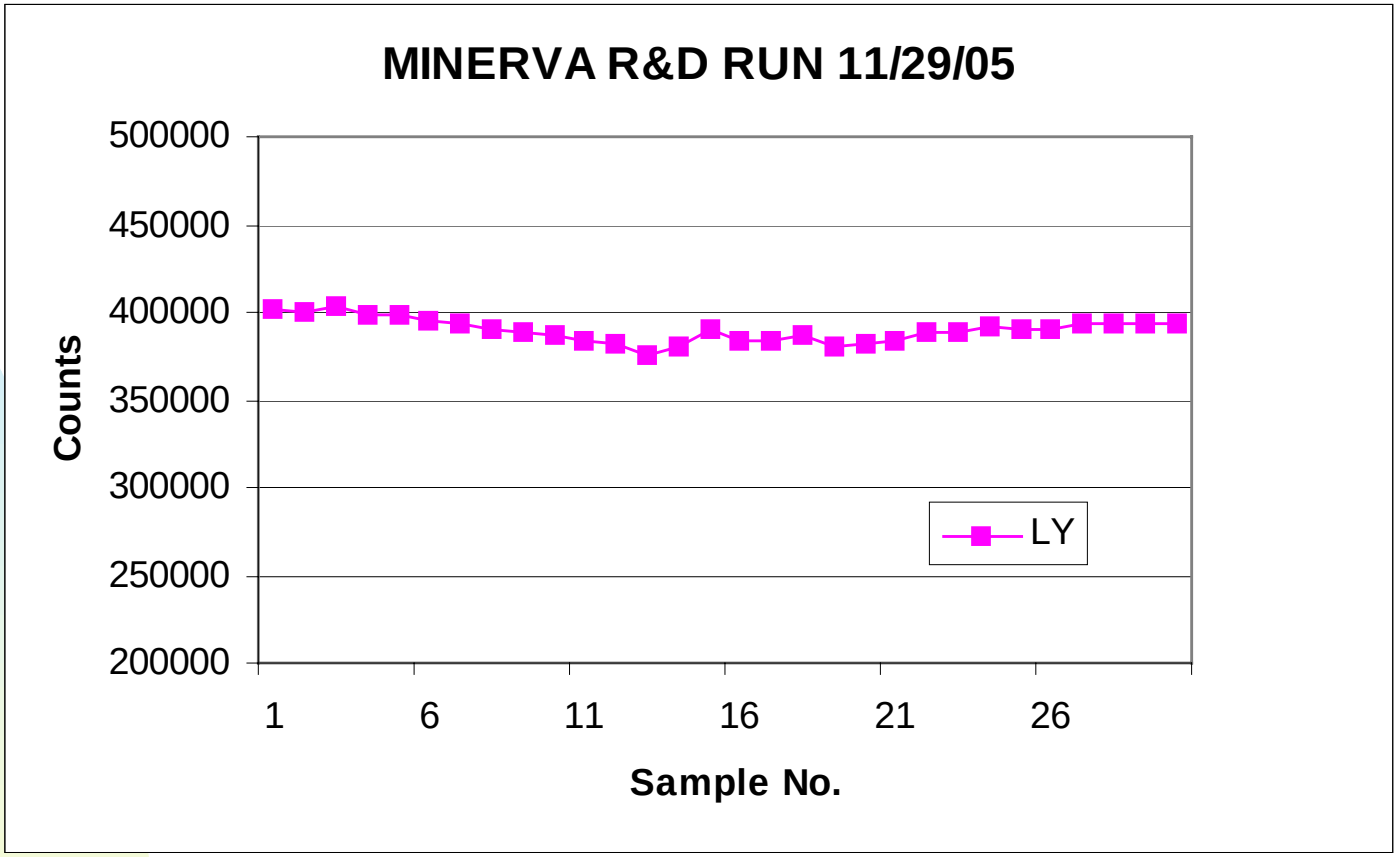




1% PPO + 0.03% POPOP

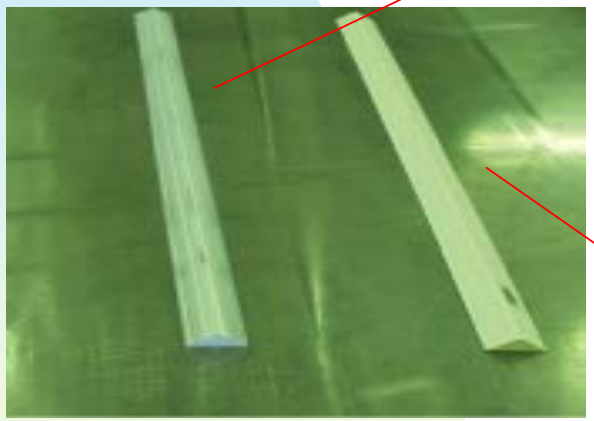


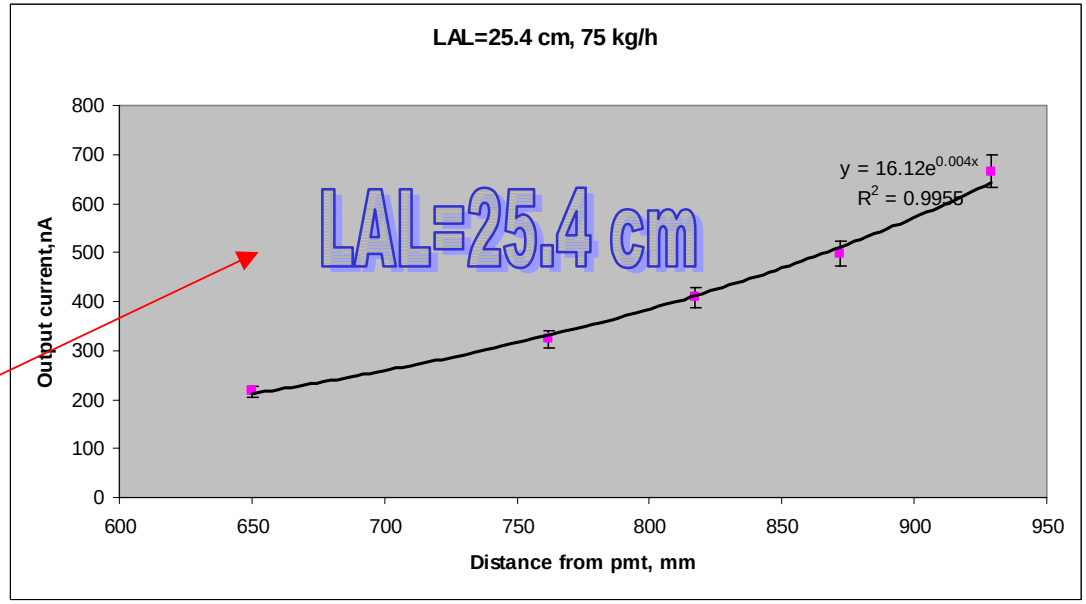
LY nonuniformity over 30 samples

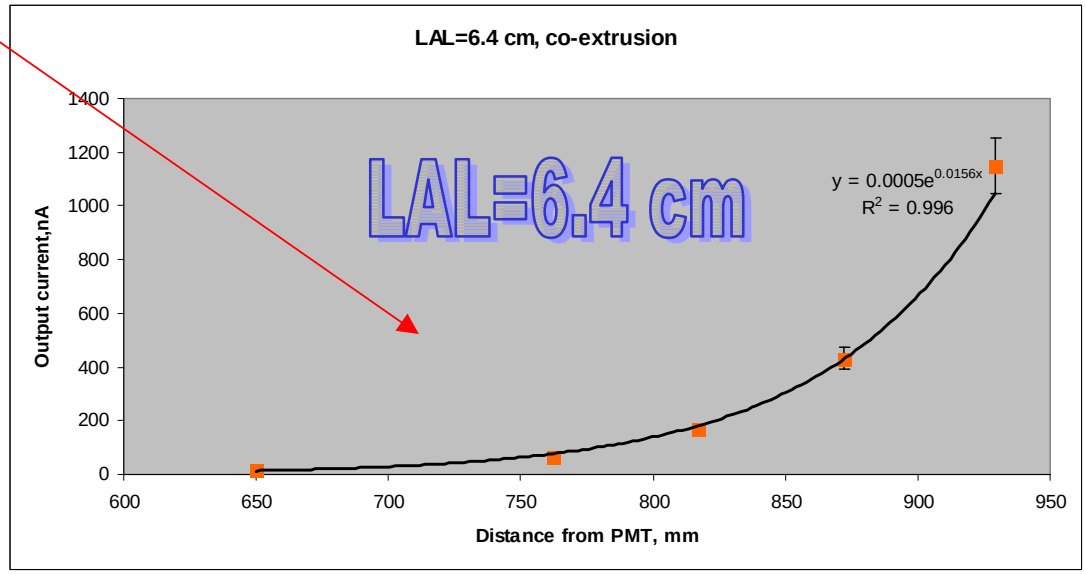


ABOUT A 5% VARIATION ! Over 200 m of extrusion

Impact of co-extrusion on Light Attenuation Length

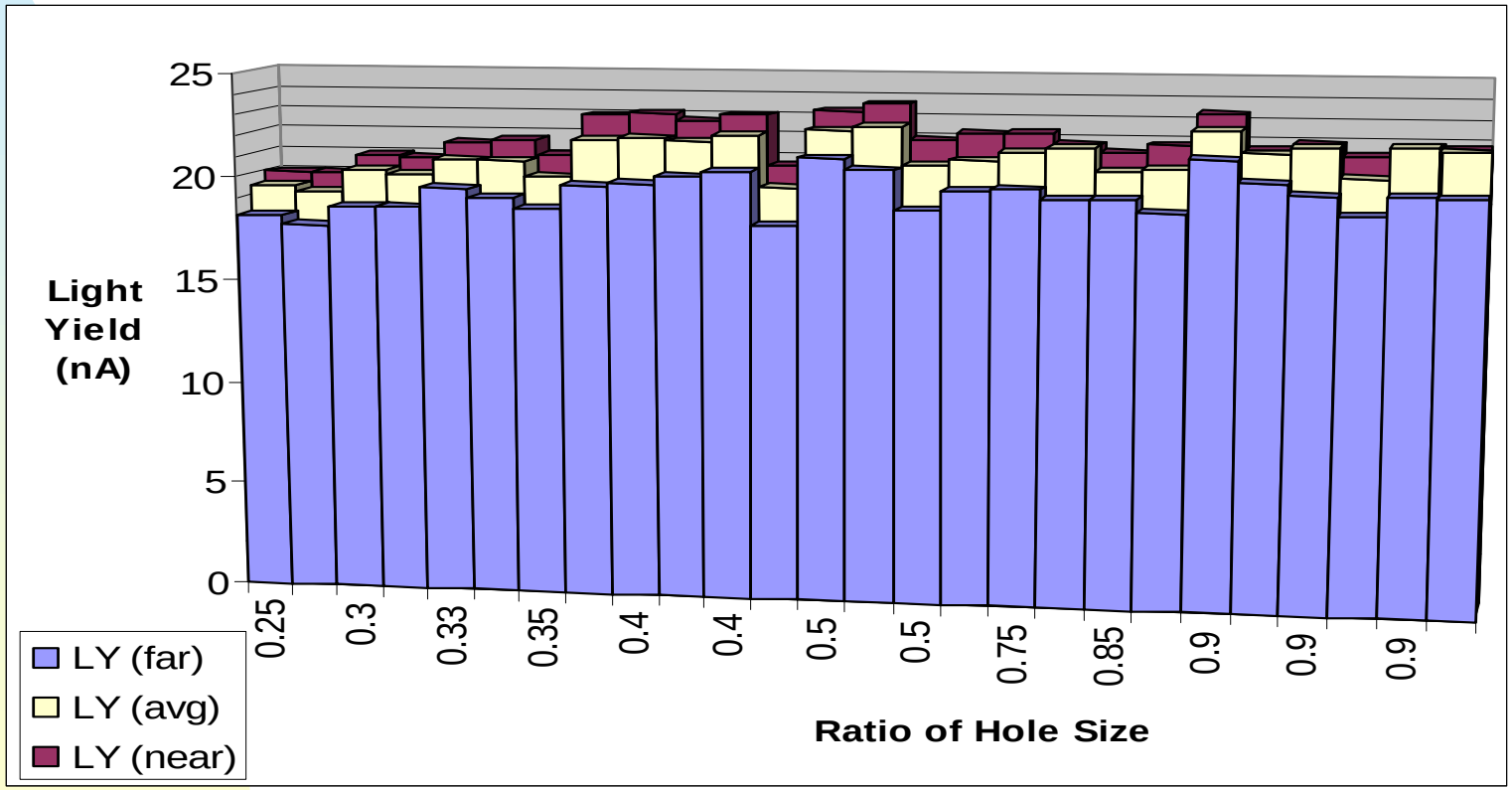






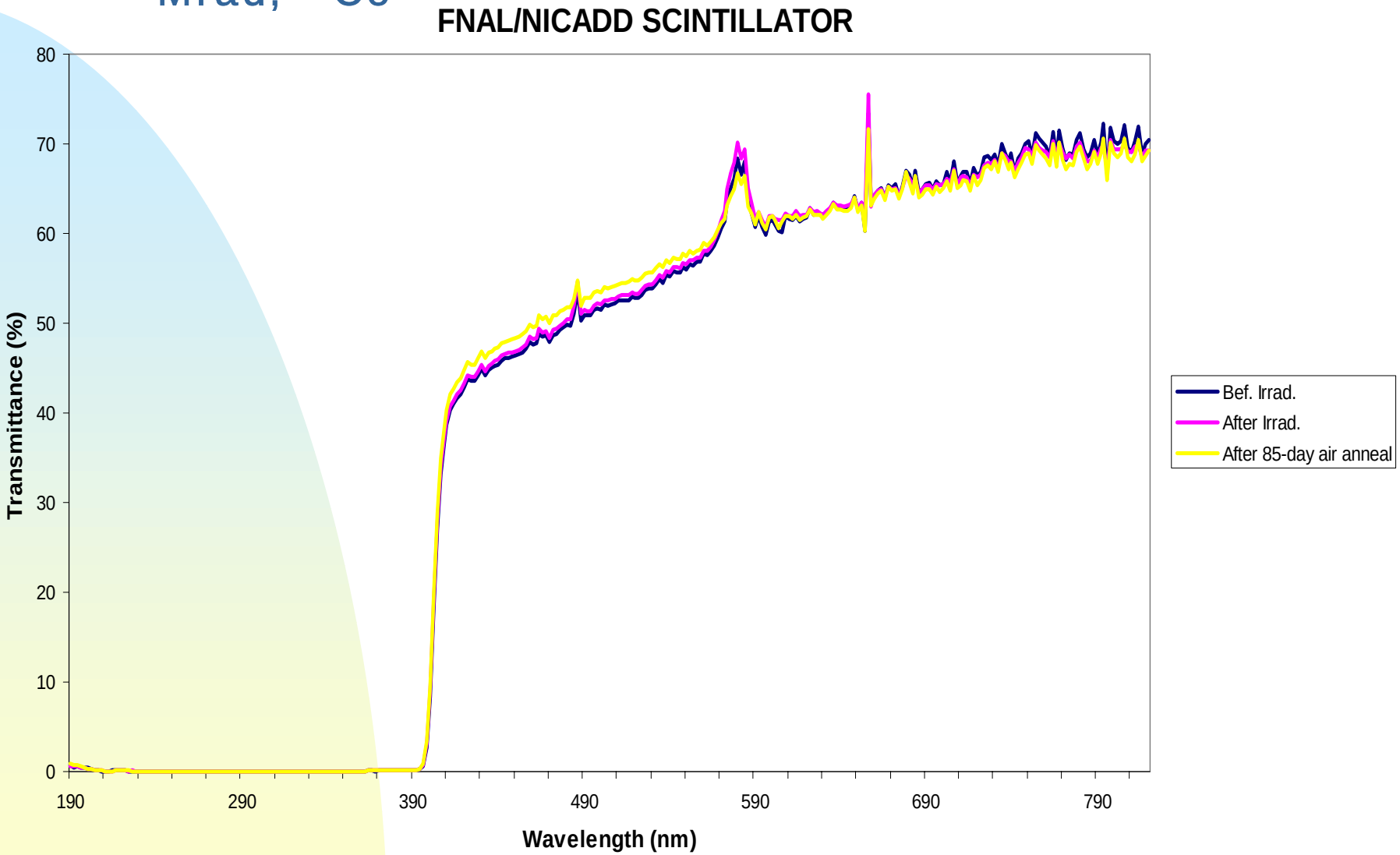
Results on the relative LY with fibers (no optical glue)

Ratio of diameters = d_{fiber}/d_{hole}



There is no significant impact on LY !

Transmittance before and after irradiation, 5 Mrad, ^{60}Co



Radiation hardness

FNAL-NICADD extruded scintillator, 18 samples of 2*2 cm^2, Irradiation in air and annealing in air during 85 days, 9 KGy/h).

Dose absorbed γ, ^{60}Co	Before Irradiation (ADC counts)	After irradiation and anneal (ADC counts)	Light yield loss
0.5 Mrad (5KGy)	264±8.6	266±7.7	
1 Mrad (10KGy)	273±5.8	261±7.1	~ 5 ±2 %

Coupling of extruded scintillator with co-extruded hole and SSPM comes in a natural way!

General introduction to SSPM

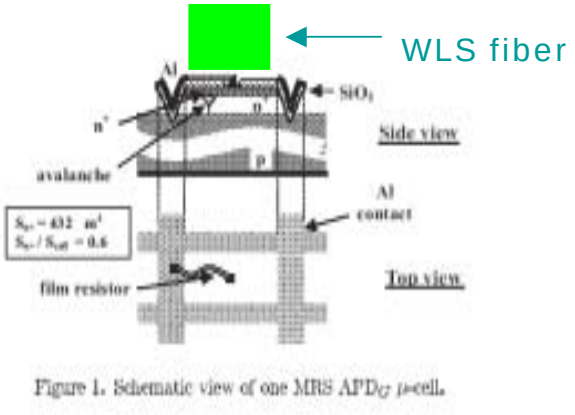
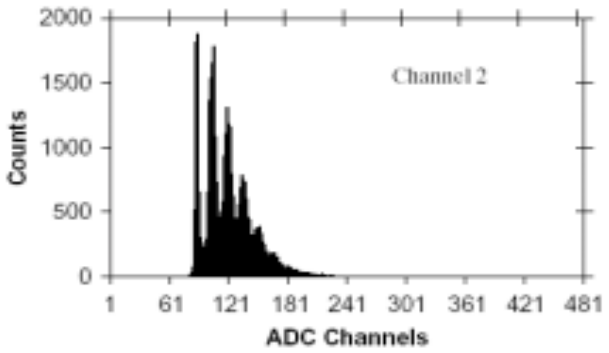
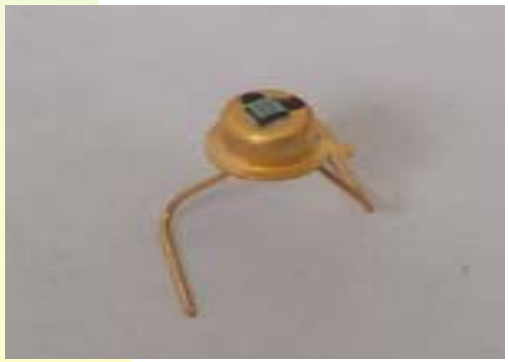
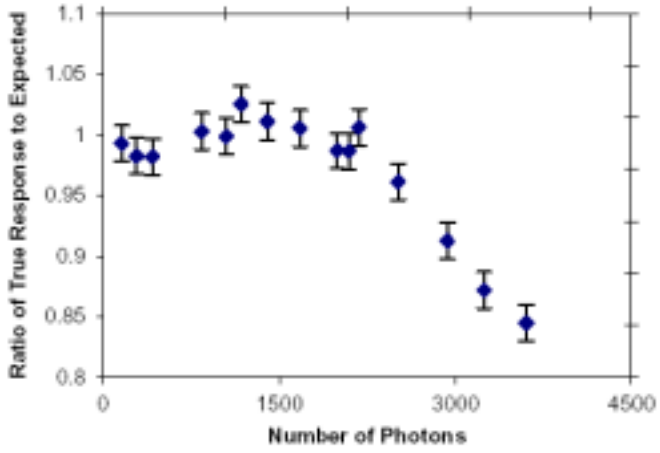


Figure 1. Schematic view of one MRS APD cell.

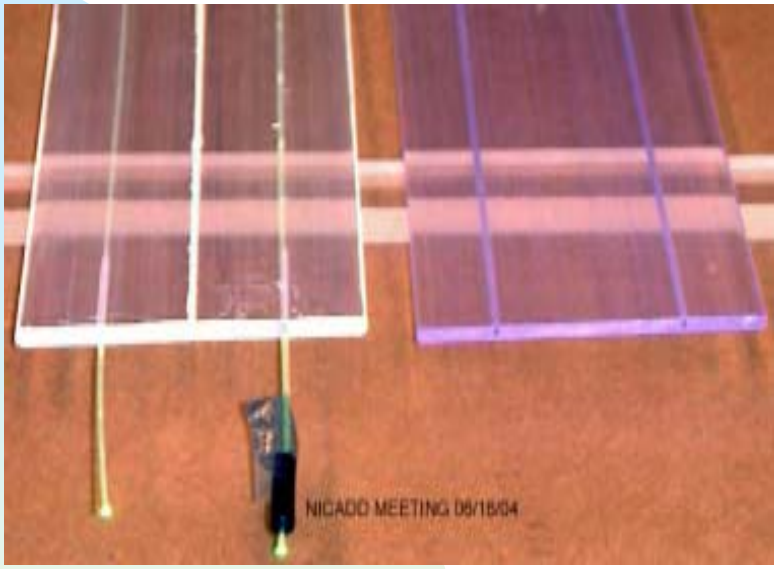
- Spectral response range 420-800 nm
- Peak sensitivity wavelength 630 nm (SSPM CPTA)
- ε (500 nm) ~ 25%*(0.4-0.6)=12-15 %
- Operating voltage 28-65 Volts
- Dark current ~ 2 μA
- Capacitance ~25 pF
- Gain ~(0.5-2)*10^6
- **Good single electron separation**
- Time response ~ 1-2 ns
- Time resolution < 300 ps

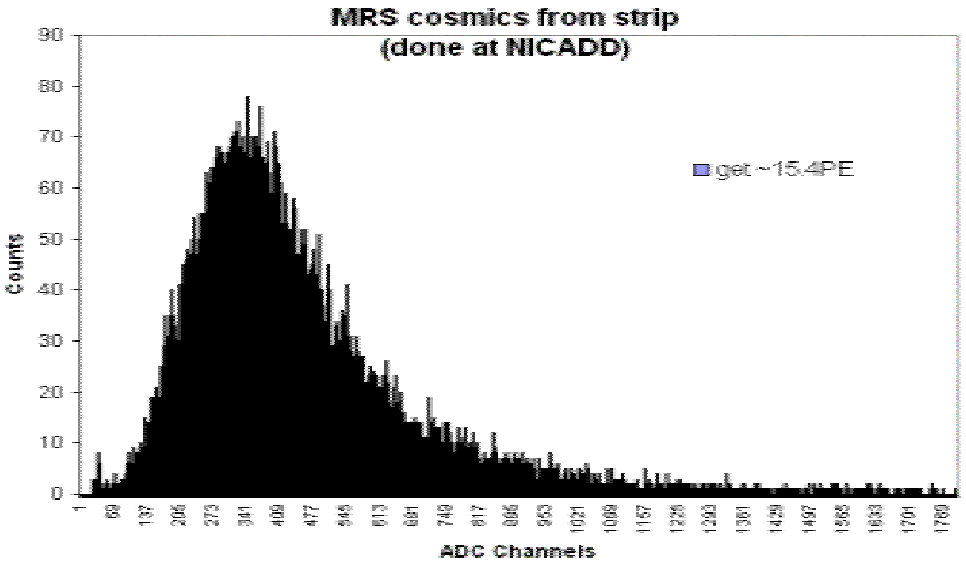






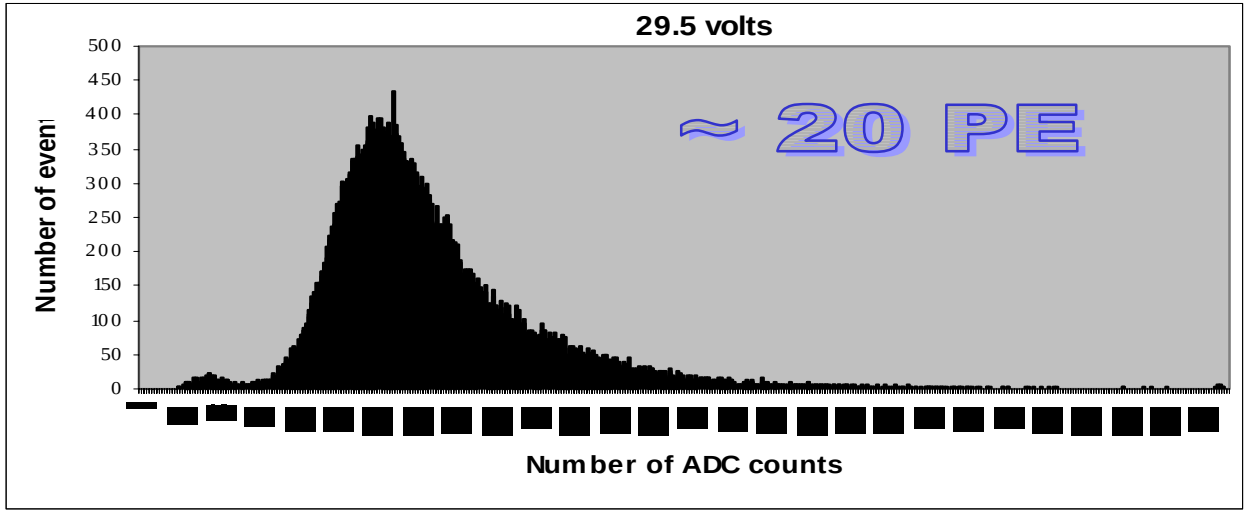
Light output SSPM (CPTA)





5 mm extruded scintillator thickness, extruded hole,1.2 mm Y11 fiber, 10 cm out of scintillator, SSPM (CPTA) readout ~ 15 PE

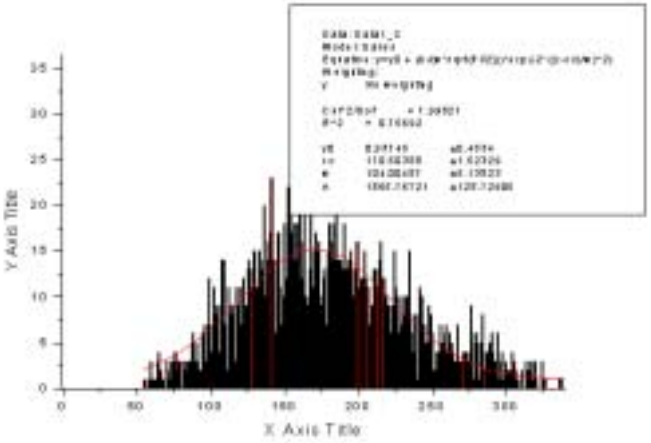
Light yield with SSPM(CPTA) read-out, co-extruded , MINOS type scintillator,Y11, 1.2 mm.

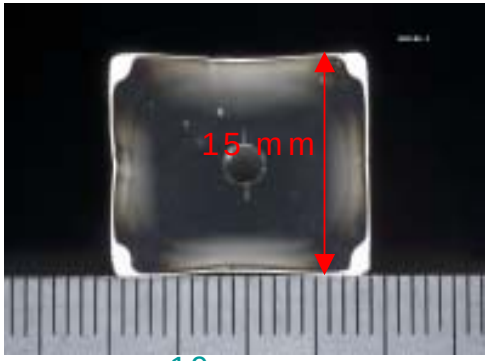


Light yield with SSPM read-out co-extruded , MINERvA rectangle type scintillator.

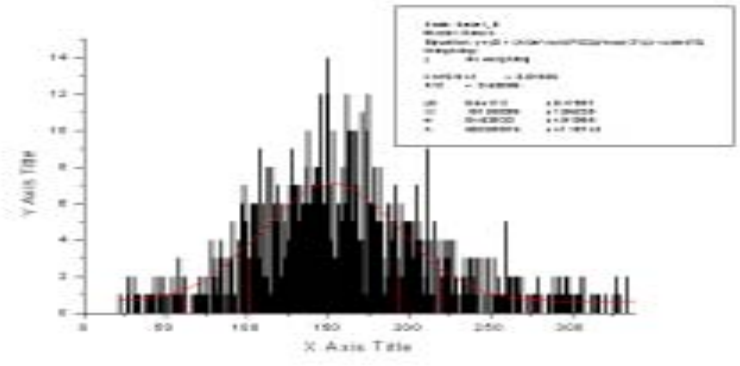
Scintillator ← SSPM

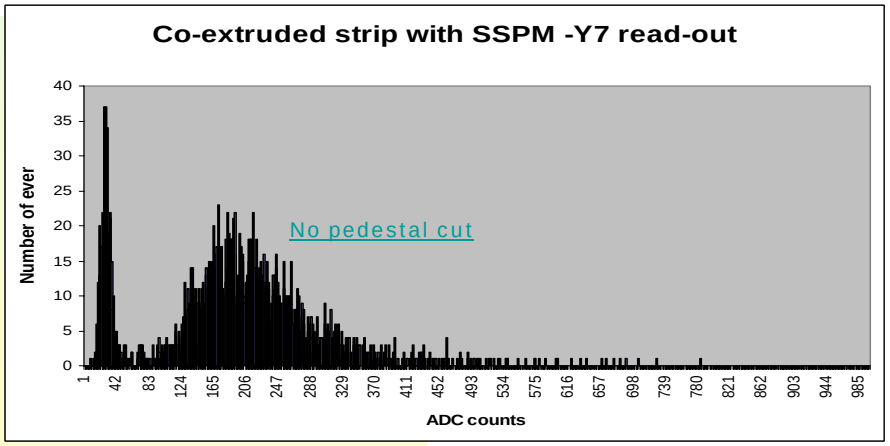
Y7 ,1.2 mm, no glue, no mirroring, 1PE=8 ADC counts, total ~ 21.3 PE, PED=30 ADC counts





Y11 ,1.2 mm, no glue, no mirroring, 1PE=8 ADC counts, total ~ 19 PE, PED=30 ADC counts





Y7/Y11= 1.12

Add optical glue(50%), mirroring(50%) one may expect

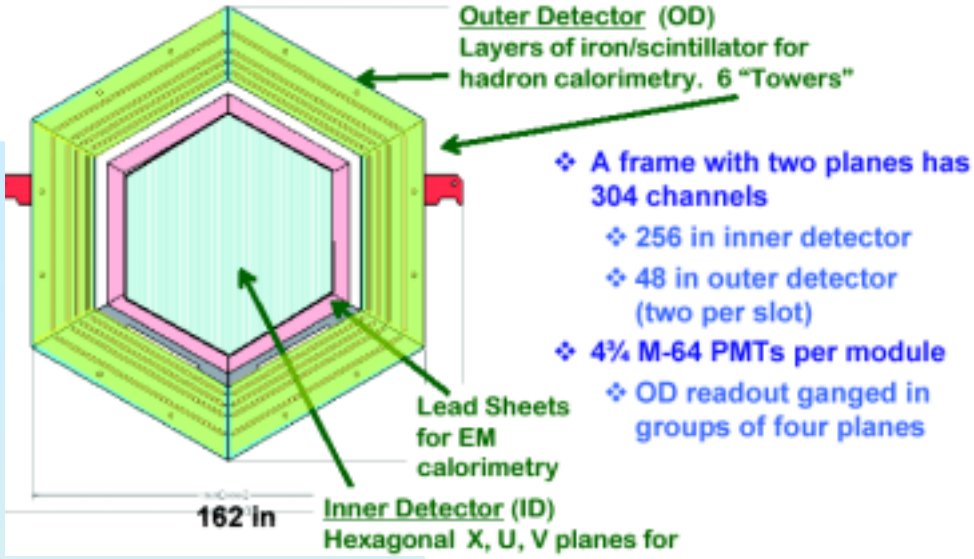
Y11= 42.7 PE

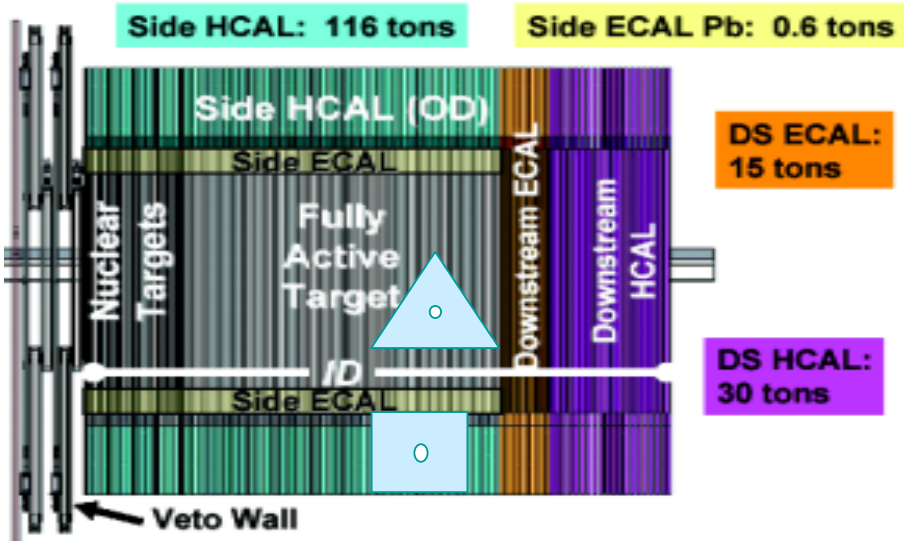
Y7 = 47.9 PE

Joint NICADD (V. Rykalin) - T2K (D. Besnosko) measurements

Experiments that are considering extruded scintillator as a base line.

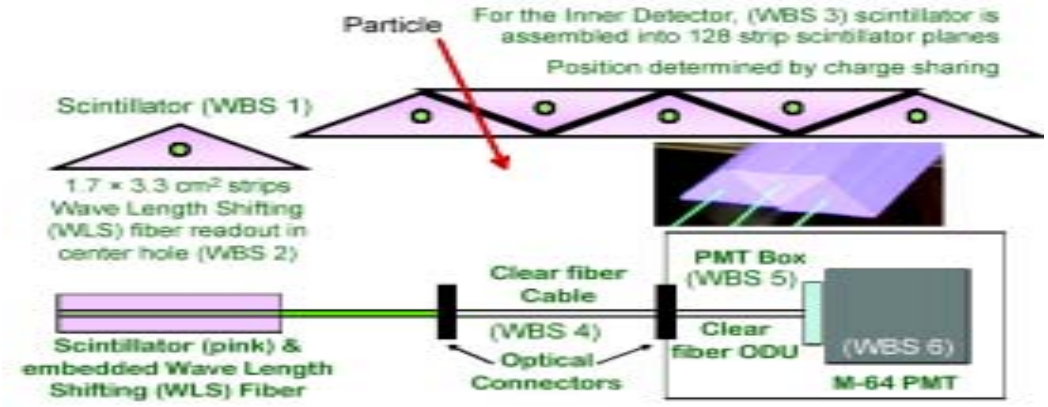
- R&D for ALICE upgrade.
- MINERvA (triangular and rectangular co-extruded (TiO2) scintillators).
  R&D stage.
  Production scheduled for 2007-2008.
- ILC (CALICE collaboration).
  TCMT, R&D completed.
  Production run in 2004.
  Scintillator has been delivered to the customer.





11 PE/MIP per doublet

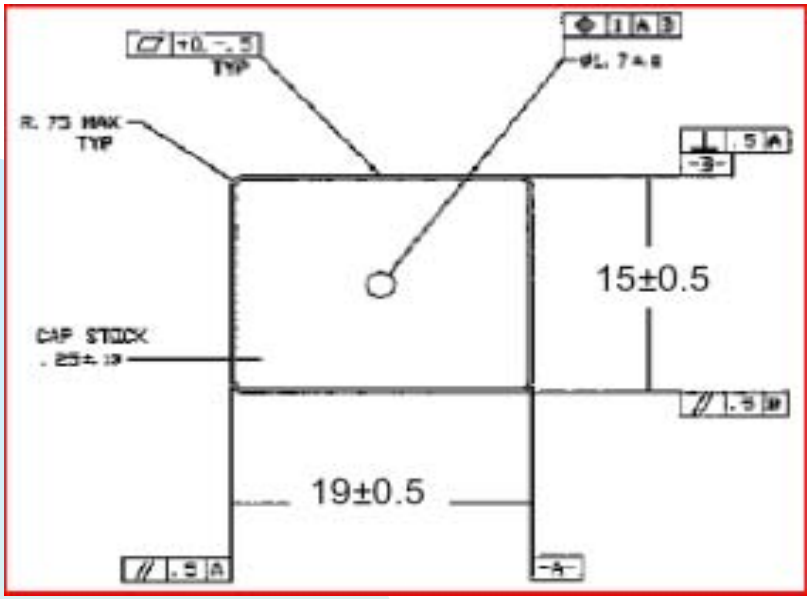
With M64 PMT read out

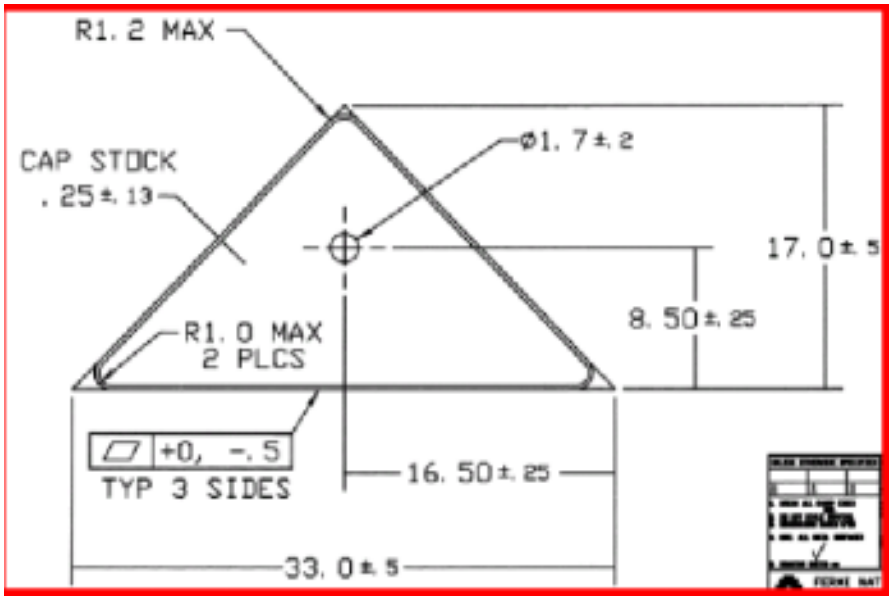


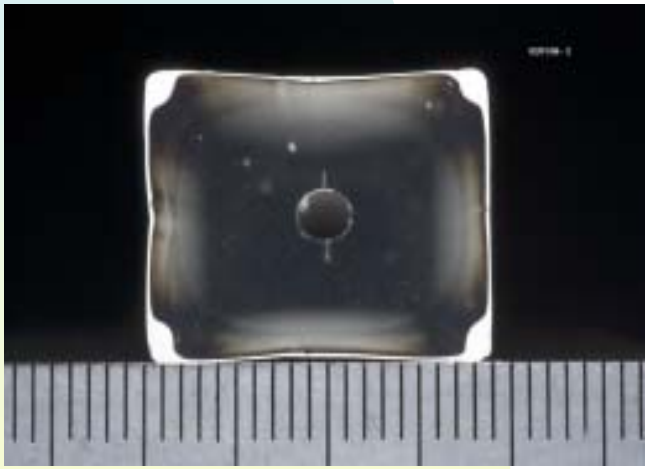
MINERvA is a dedicated low-energy neutrino nucleus scattering experiment to be installed in the NuMI near hall.

Main goals are measurements of low-energy exclusive and inclusive neutrino cross sections and studies of the nuclear effects on these cross sections and on neutrino-induced hadron showers.

More about MINERvA **http://minerva.fnal.gov/**







Total of 60,128 m , co-extruded plastic.

The total amount of co-extruded scintillator is

ID **13,312 triangular strips – 3.80 m long**

OD **2,736 square strips – 3.5 m long**

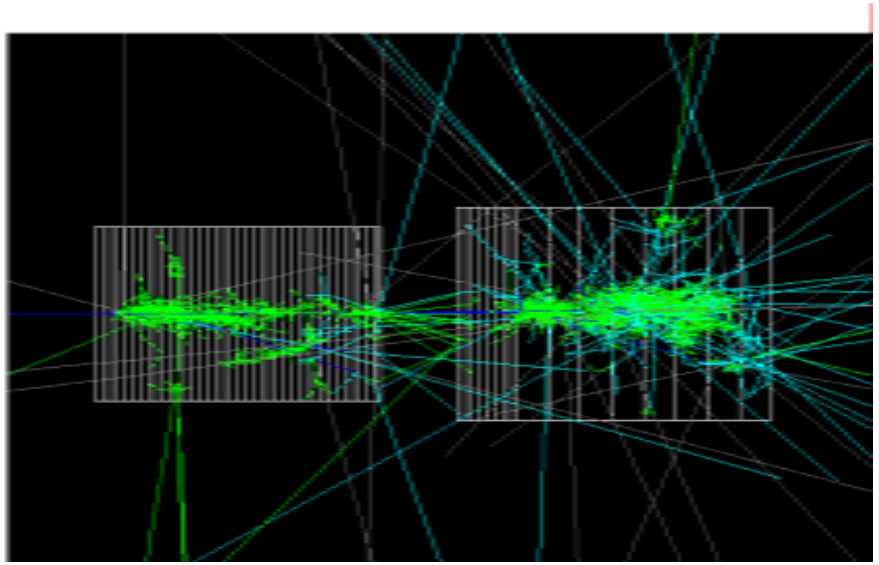
ILC R&D program (CALICE collaboration)

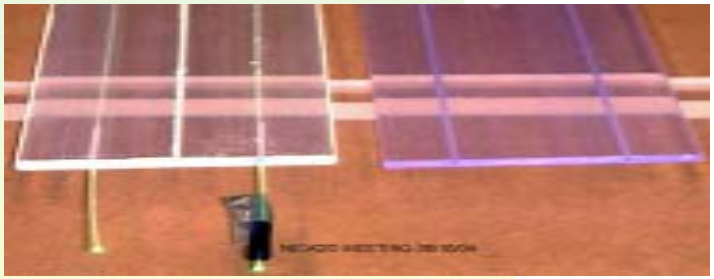
* **As a precision instrument for the calorimeter is essential to get a jet energy resolution dE/E~30% /√E.**

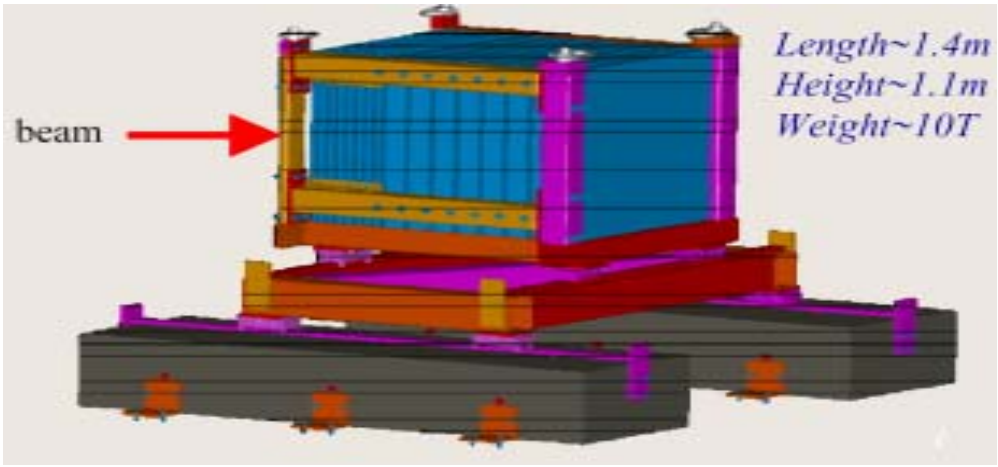
* **A complete calorimeter system includes an integrated tail-catcher and muon system(with extruded scintillator as active media) to be located behind the ECAL and HCAL.**

Tail-Catcher uses ~ 300 m of extruded plastic scintillator with co-extruded hole (100cm*10cm *0.5cm)

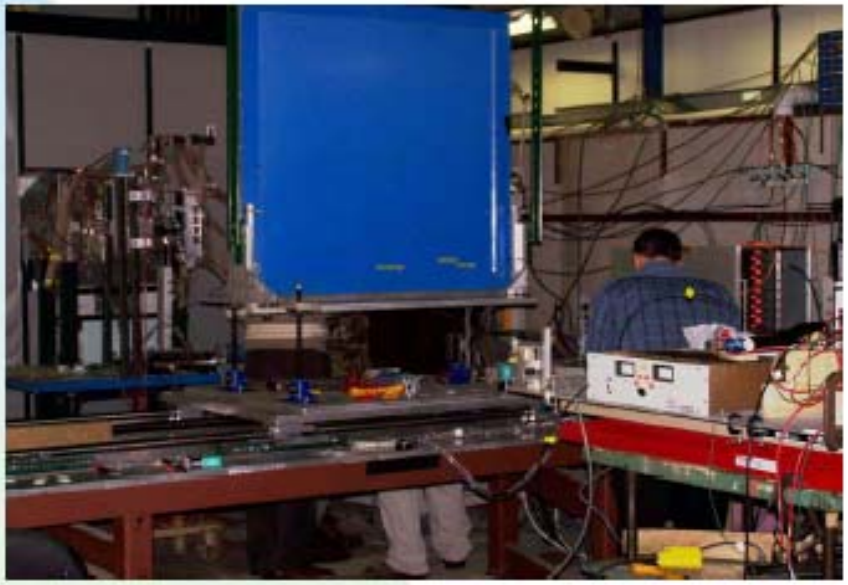
A. Dyshkant with more details on TCMT







ILC (CALICE collaboration)



NICADD - FNAL extruded schintillator, 5 mm thickness, WLS Y-11, no glue (without co-extrusion)

NICADD participates in TCMT, DIGITAL HCAL

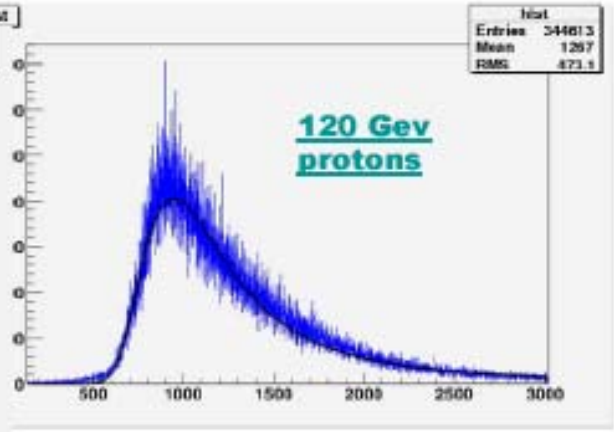
TEST beams , electrons, protons

Future tests at CERN

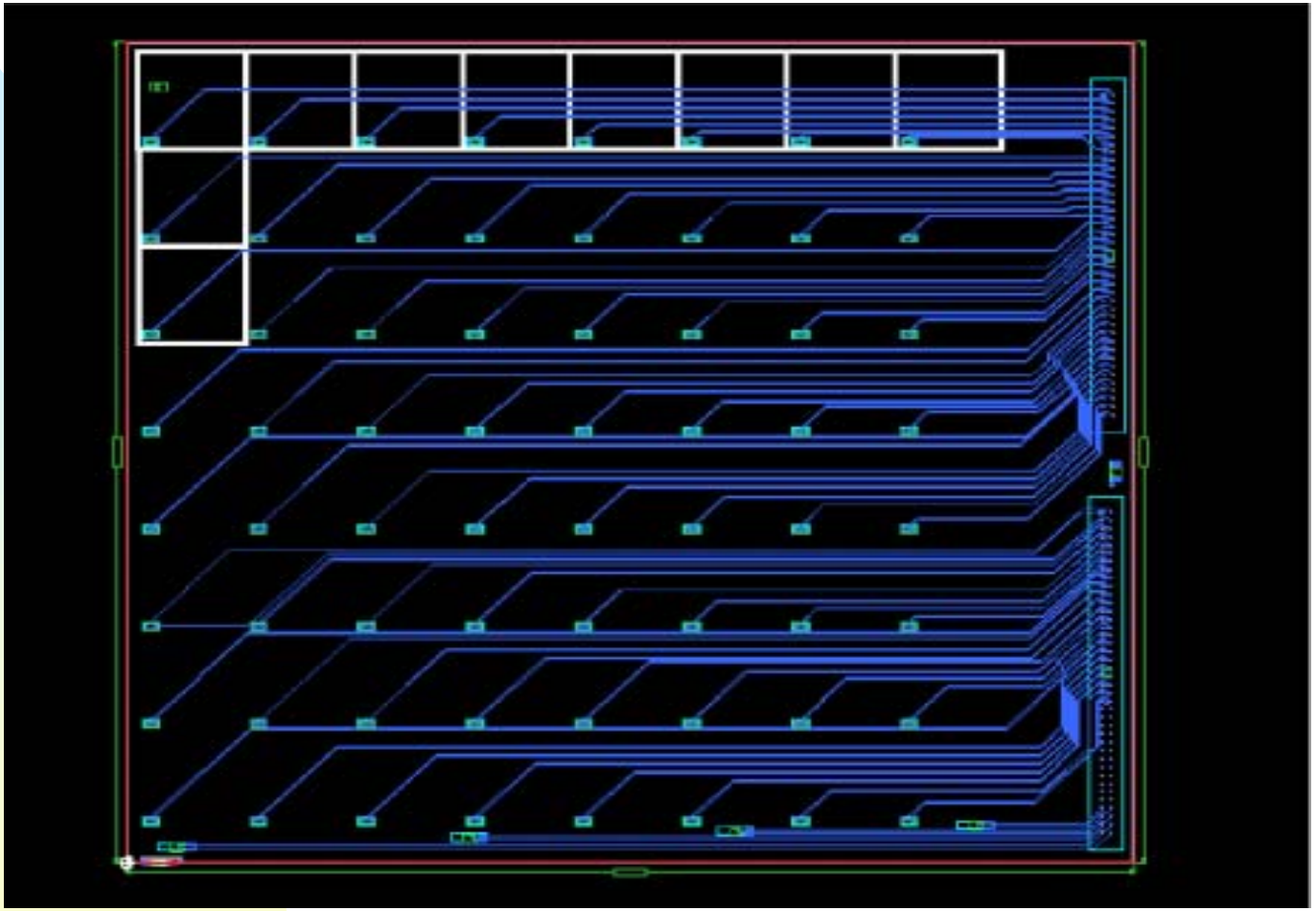
Working DAQ (common for the CALICE collaboration) is running at MTBF and can be used for other tests.

10-14 PE per strip as average

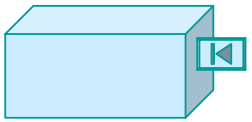
SSPM, Pulsar

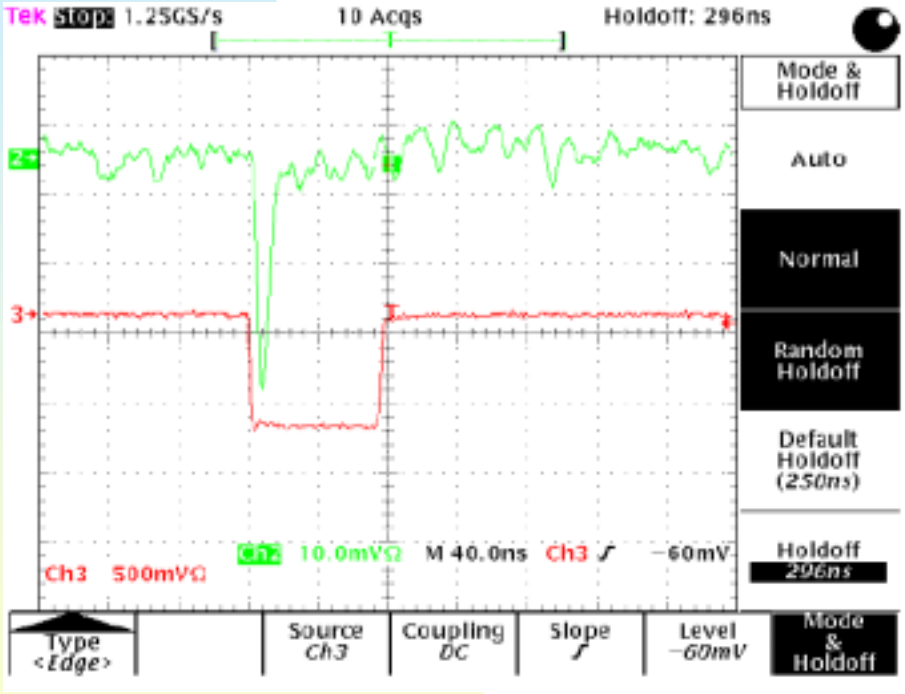


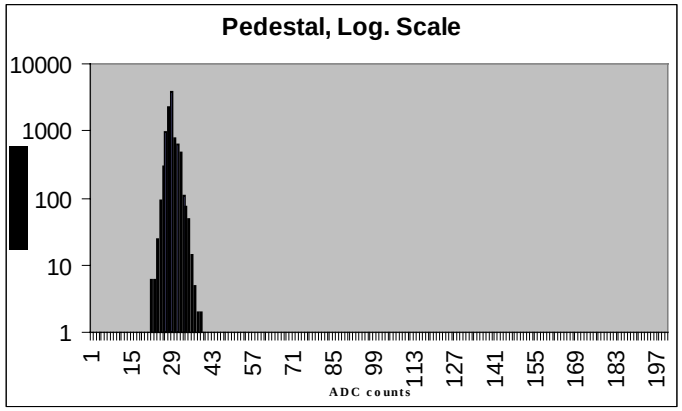
ILC R&D. Direct coupling of extruded scintillator and SSPM ?

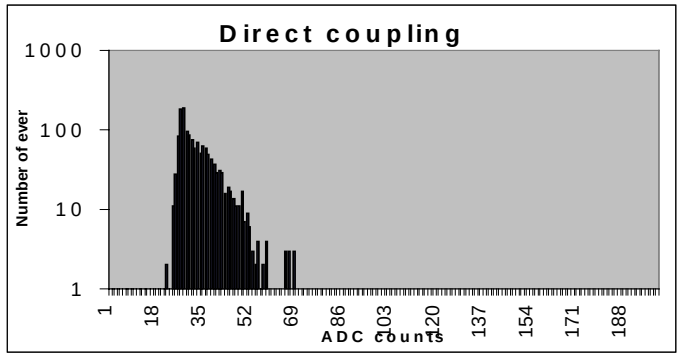


Direct SSPM-scintillator read-out by SSPM(CPTA), QE (420 nm) ~ 2 %, 2*2 cm, 5 mm thickness, extruded scintillator, cosmic events.









! Sensitive area is 1*1 mm^2

Summary

- **Cheap and robust scintillator built based on the developed extrusion technique.**
- **Successful application of the extruded scintillator for MINERvA R&D, ILC R&D.**
- **SSPM read-out developed for the extruded scintillator.**
  SSPM perfectly matches this application.
- **More R&D is under way.**